ON THE

RELATIVE POWERS OF VARIOUS SUBSTANCES

IN

PREVENTING THE GENERATION OF ANIMALCULÆ

OR THE DEVELOPMENT OF THEIR GERMS;

WITH

SPECIAL REFERENCE TO THE GERM THEORY OF PUTREFACTION.

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IN PREVENTING THE GENERATION OF ANIMALCULÆ OR THE DEVELOPMENT OF THEIR GERMS.

THE words GENERATION and DEVELOPMENT are here used so as to embrace the two opposite views held by the Panspermatists and the Nonpanspermatists; or, to employ the terms adopted by Professor Huxley last year, the words are meant to embrace the two conflicting theories of Biogenisis and of Abiogenisis; the Panspermatists, or Biogenists, believing that all life is derived from pre-existing life—"*omne vivum ex vivo*"—while the Nonpanspermatists, or Abiogenists, hold that certain combinations of dead matter are capable, in favourable circumstances, of originating many of those functions which are termed *vital.* In other words, they assert that spontaneous generation is not only possible but demonstrable.

It is not fairly within the scope of my subject to discuss the question at issue, nor does it appear that any modifications are required in the brilliant array of facts which Professor Huxley marshalled last year in defence of Biogenisis, nor that any serious doubts have been entertained regarding the accuracy of the very interesting and apparently practically exhaustive experiments of Dr. C. Bastian, which seem to prove Abiogenisis.

My object was not to inquire whether those amazingly minute animated specks, called in general terms Animalculæ, are generated or developed, but how their propagation could be retarded or altogether prevented.

As certain substances are inimical to the existence of the higher

organic structures, so also are they, to a considerable extent, adverse to animalcular vitality. Hence the assumed latent principle of life in the hypothetical germ of the Biogenist may be enfeebled or stifled, and the supposed subtle essence which is ready to permeate and vivify—to endue with perception and appetite the protean molecules of the Abiogenist—arrested or destroyed. In either view the result is the same—the non-appearance of life in solutions otherwise favourable to its production, caused by the addition of certain chemical substances of given strengths, and diffusible in the Animalculæ producing media.

Three series of experiments were made—one with vegetable and two with animal matter—of which the following are a few of the more important details:—

Sixty-seven substances were selected for trial, consisting of irritant, narcotic, and narcotico-irritant poisons; also several others whose sensible properties, or alleged antiseptic powers, recommended them as worthy of experiment. Nitrate of ammonium, and Spirits of nitric ether were added for contrast. Sulphite of soda, Perchloride of iron, and one or two other such bodies, were unintentionally omitted.

To three drams of a solution, consisting of one part of the substance to be tested, in 500 parts of water, was added one dram of a filtered infusion of hay, of the strength of half a dram of dried hay to a fluid ounce. This mixture was put into a phial. Where the substance was volatile the phial was kept closed, otherwise it was left open.

The *modus operandi* with the animal substances was similar, the only difference being that human urine was substituted for infusion of hay in one set of experiments, and a mixture of beef juice and egg albumen in another; while only half a dram of the latter mixture was added to three drams and a half of the test solutions. Three blank experiments were first made, *i.e.*, three phials were filled respectively with water and infusion of hay, water and urine, and water with juice of flesh and egg albumen only, in order that

any contrast in the growth of animalculæ, in the simple, and supposed preventive solutions might be noted. All the phials when filled were placed in a medium temperature of about 60° Fahrenheit, and exposed to a moderate light. In two to six days the microscopical examination of each series, with a magnifying power of 700 diameters, was begun and concluded. The simple solutions were found teeming with Bacteria, Vibriones, Monads, Amoebae, Torulae, &c. The results of the examination of the various test solutions were necessarily of two kinds—*life*, or *no life*; the one or other being inferred from the presence or absence of moving bodies only. No notice was taken of fungi, which were generally more or less present, especially in the vegetable solutions.

In those cases where motion was perceived, the phials were refilled with stronger solutions; conversely, weaker solutions were tried, and after being allowed to stand as before, were again examined microscopically and the process repeated till a point was gained where none, or only the faintest movement was perceptible. Here the strength of the solution was ascertained, and its preventive power noted, *i.e.*, the quantity of the foreign substance in the mixture in which no animalculæ were observed after the lapse of six clear days.

When the experiments had been concluded in the manner stated, they were repeated as follows, in order to confirm or correct previous results:—

Separate solutions were prepared of the various substances, each of its recorded preventive strength, with the same proportions of each of the organic fluids added as hitherto. They were then set aside under the same circumstances, for the same length of time, and again examined microscopically, and the results finally adopted.

It may be stated that most of the solutions had to be examined from three to eight times in each of the three series of experiments; the strength of the separate mixtures requiring to be either augmented or diminished at every inspection, before their preventive powers could be ascertained.

TABLE *shewing the amount of various substances which prevents the appearance of Animalculæ in six days at about 60° Fahrenheit, when added to Infusion of Hay, to Human Urine, and to a mixture of Beef Juice and Egg Albumen.*

I. METALLIC SALTS.	Hay.	Urine.	Beef Juice & Albumen.	Average.
Sulphate of Copper, . . .	1-1000	1-1000	1-800	1-933·3
Bichloride of Mercury, . .	1-700	1-700 f.p.*	1-500	1-633·3
Protosulphate of Iron, . .	1-500	1-500	1-100	1-366·6
Arsenious Acid, ...	1-750	1-150	1-50	1-316·6
Sulphate of Iron and Potassium (Iron Alum), ...	1-300	1-300	1-300	1-300
Acetate of Lead, ...	1-300	1-300	1-300	1-300
Tartrate of Antimony, . .	1-300	1-300 f.p.	1-300	1-300
Chloride of Zinc, ...	1-300	1-300 f.p.	1-300	1-300
Sulphate of Zinc, ...	1-300	1-300 f.p.	1-200	1-266·6
Bichloride of Platinum, . .	1-250	1-250	1-150	1-216·6
Nitrate of Silver, ...	1-300	1-100	1-50	1-150
Average, ...	1-454·54	1-381·8	1-277·27	†1-371·18
II. ORGANIC ACIDS.				
Benzoic, ...	1-700	1-700	1-200	1-533·3
Hydrocyanic (B.P.), ** . .	1-500	1-500 f.p.	1-500 f.p.	1-500
Picric, ...	1-350	1-350	1-350	1-350
Oxalic, ...	1-350	1-350	1-200	1-300
Carbolic, ...	1-300	1-300	1-200	1-266·6
Tartaric, ...	1-300	1-100 f.p.	‡ ,,	1-133·3
Acetic (B.P.), ...	1-350	1-25	,,	1-125
Average, ...	1-407·1	1-332·1	1-207	1-315·45
III. Salts of the Alkaline Earths.				
Chloride of Aluminum, . .	1-2000	1-500 f.p.	1-300	1-933·3
Sulphate of Aluminum and Potassium (Alum), . . .	1-800	1-500 f.p.	1-100	1-466·6
Solution of Chloride of Calcium,	1-200	1-200	1-25	1-141·6
Chloralum (Commercial), . .	1-300	1-50	1-50	1-133·3
Sulphate of Magnesia, . .	1-250	1-50	,,	1-100
Bisulphite of Lime, . . .	1-100	1-50	1-25	1-58·3
Average, ...	1-608·3	1-225	1-83·3	1.305·5
IV. INORGANIC ACIDS.				
Sulphuric, B.P., ...	1-800	1-500	1-100	1-466·6
Nitric (B.P.), ...	1-400	1-400	1-200	1-333·3
Hydrochloric (B.P.), . . .	1-500	1-400 f.p.	1-100	1-333·3
Nitro-Hydrochloric (B.P.), .	1-250	1-250	1-100	1-200
Sulphurous (B.P.), . . .	1-250	1-50	1-50	1-116·6
Average, ...	1-440	1-320	1-110	1-289·96
V. ALCOHOL and its DERIVATIVES				
Bromal Hydrate,. . . .	1-500	1-500	1-500	1-500
Chloral Hydrate, ...	1-600	1-600 f.p.	1-300	1-500
Perchloride of Formyle (Chloroform)	1-500	1-400 f.p.	1-25	1-308·3
Alcohol, ...	1-350	1-50	1-20	1-140
Spirits of Nitrous Ether, . .	1-350	,,	,,	1-116·6
Acetone, ...	1-100	,,	,,	1-33·3
Average, ...	1-400	1-258·3	1-140·83	1-266·33
VI. INORGANIC BASES.				
Tincture of Iodine, . . .	1-400	1-400	1-50	1-283·3
Caustic Potash, ...	1-300	1·50	1-10 very putrid.	1-120
Average,	1-350	1-225	1-30	1-201·6

VII. ORGANIC SALTS.	Hay.	Urine.	Beef Juice & Albumen.	Average.
Hydrochlorate of Strychnia, .	1-450	1-450	1-300	1-400
Sulphate of Beberia, . . .	1-500	1-25	1-25	1-183·3
Acetate of Morphia, . . .	1-500	1-25	,,	1-175
Stearate of Soda (Hard Soap), .	1-25	1-25 f.p.	1-25	1-25
Average, ...	1-368·75	1-131·3	1-87·5	1-195·8
VIII. Inorganic Alkaline Salts.				
Bichromate of Potassium, . .	1-900	1-900	1-900	1-900
Permanganate of Do. . .	1-500	1-200	1-125	1-275
Chlorate of Do. . .	1-500	,,	,,	1-166·6
Hyposulphite of Soda, . .	1-250	,,	,,	1-83·3
Borate of Soda, ...	1-200	,,	,,	1-66·6
Condy's Fluid, ...	1-200	,,	,,	1-66·6
Sulphate of Soda, . . .	1-75	,,	,,	1-25
Chloride of Do., . . .	1-25	,,	,,	1-8·3
Nitrate of Ammonium, . .	1-25	,,	,,	1-8·3
Average, ...	1-297·2	1-122·2	1-113·88	1-177·76
IX. VOLATILE GUMS.				
Camphor, ...	1-300	1-150 f.p.	1-50	1-166·6
X. AROMATIC OILS.				
Oil of Carraway, . . .	1-400	,,	,,	1 133·3
Oil of Cassia, ...	1-400	,,	,,	1-133·3
Oil of Peppermint, . . .	1-250	,,	,,	1-83·3
Average, ...	1-350			1-116·6
XI. ORGANIC BASES.				
Glycerine, ...	1-300	,,	,,	1-100
XII. BITTER EXTRACTS.				
Aqueous Extract of Quassia, .	1-50	,,	,,	1-16·6
XIII. ANIMAL SUBSTANCES.				
Tincture of Musk, . . .	1-50	,,	,,	1-16·6
Spirituous Extract of Cantharides, ...	,,	,,	,,	,,
XIV. AROMATIC EXTRACTS.				
Spirituous Extract of Capsicum (Cayenne), ...	1-25	,,	,,	1-8·3
XV. Poisonous Vegetable Extracts, Spirituous and Aqueous.§				
Extract of Aconite, . . .	,,	,,	,,	,,
Extract of Belladonna, . .	,,	,,	,,	,,
Extract of Calabar Bean, .	,,	,,	,,	,,
Extract of Digitalis, . .	,,	,,	,,	,,
Extract of Lobelia, . . .	,,	,,	,,	,,
Extract of Tobacco, . . .	,,	,,	,,	,,
Extract of Curara, . . .	,,	,,	,,	,,

* F.P. denotes faint putrescence. Where these letters are absent, the mixture remained free of odour.

** B.P denotes British Pharmacopoeia.

† The average of the averages in right hand column corresponds with the average of the three averages of the perpendicular columns.

‡ The various blanks in the columns indicate that the substances opposite which they are placed are incapable of preventing putrefaction and the appearance of animalculæ at 1-10.

§ Simple aqueous solutions of the poisonous vegetable extracts soon teem with life.

Note.—The parts of water indicated in the tables represent dropped minims, forty to the dram.

Example.—1-500 signifies one grain, if the chemical substance be a solid, or one dropped minim, if a fluid, in 500 minims of water, forty of which make one dram.

The substances used have been classified into fifteen groups, according to their chemical relations—placing the group that shows the highest average preventive power "first" on the table, and the one that shows the lowest, "last." The various substances have also been tabulated in their respective groups on the same principle.

The metallic salts, from their showing the highest average preventive power, viz., 1-371·18, form Group I. Sulphate of copper here has not only the highest individual average, but its three preventive points, in the three solutions, are very much higher than those of any other substance in the group. Nitrate of silver, on the other hand, exhibits the lowest individual average. This is undoubtedly to be attributed to its peculiar property of being decomposed by the combined action of light and organic matter, and further, in the urinous solution, by the chlorides present. The results of the acetate of lead, in the urinous solution, are also affected by the same cause, viz., the formation of the insoluble chloride. The metallic salts as a body are very uniform in their action.

In Group II., the organic acids, "benzoic" has the highest, and "acetic" the lowest average preventive power. Of the seven members composing this group, carbolic acid occupies the fifth rank. There are also two blanks in the albumen column—the one opposite "acetic" and the other opposite "tartaric" acid, indicating that these are incapable of preventing the appearance of animalculæ in the albuminous solution at 1-10.

Group III., Salts of the alkaline earths. Here chloride of aluminum is "highest" (I do not refer, of course, to the commercial liquid chloralum, which, however, has been included), and a sulphurous smelling fluid, said to be bisulphite of lime, "lowest." Were it not for the extremely high average (1-2000) of the chloride of aluminum in the hay column, this group would occupy a comparatively subordinate position. Sulphate of magnesia is blank in the albumen column.

The average of Group VIII., inorganic alkaline salts, would be

"extremely low" were it not for that of the bichromate of potassium. which has the "very high" average of 1-900. The salts of soda and Condy's fluid are all blank in the urine and albumen columns, except the borate of soda, which, however, has a merely nominal preventive power.

Group X. The aromatic oils are inert in the urinous and albuminous solutions, but show good averages in hay.

Group XIII. Animal substances. Here the extract of cantharides shows three entire blanks, while the tincture of musk is blank in the urine and albumen columns.

Group XV. The poisonous vegetable extracts show blanks in all the columns, which is not surprising, seeing that their aqueous solutions, *per se*, soon teem with life.

These are a few of the more prominent points in the tables to which it has been thought worth calling attention.

On comparing the preventive powers of the different substances, in the various solutions, it is found, without exception, that the figures in the urine and albumen columns, though generally less than, and often equal to, never exceed, those in the hay column. Similar relations exist between the urine and albumen; *e.g.*, the preventive powers of a substance may be equal in both solutions, still that in the "albuminous" never surpasses that in the "urinous," and though occasionally equal, is often less. This principle is rendered easily apparent by contrasting the three average preventive powers of the three solutions of any entire group, when it will be found that a higher per centage, of all the individual substances of the group, is required to prevent the appearance of animalculæ in urine, than in hay, and a still higher in albumen than in urine.

This seems accounted for as follows:—Premising that an infusion of hay is poorer in organic matter than urine, and that the latter fluid is less rich than albumen, it appears, from the experiments, that the germ generating or developing force is strongest where the organic matter is richest, and weakest where the organic matter is

poorest. Hence the "quantity" of the "preventive" substance requires to be proportioned to the "quality" of the "organic."

But this principle applies only to averages. The preventive points of many single substances are equal in the three solutions; seemingly indicating that the potential vital energies of the latter are also equal; this view, however, is obviously unsatisfactory, the cause probably being some peculiarity in the preventive body.

It is to be remembered, also, that the averages given only hold good in the limits stated. It is possible, nay, highly probable, that were the incubatory stage prolonged in those cases where "*no life*" is recorded, "*abundant life*" might be the result. Hence the preventive points would require to be lowered—strengthened, in proportion as this stage was extended.

In those cases, again, where life persists at 1-10, it is quite likely that were the strength of the trial substance increased, so that, where possible, instead of it constituting the "minimum" proportion in the fluid in which it is dissolved, it composed the "maximum," we should have to report, instead of "*life*," "*no life*." In other words, it is not meant that these substances are not preventive at all, but, simply, that they are not preventive at 1-10, in the time, and at the temperature, stated.

It may be assumed, to a very limited extent, that, in several cases, solutions somewhat weaker, than those recorded, might be preventive. Any error, however, in this respect, is on the side of safety; having made sure that the strengths enumerated are reliable.

Although a higher magnifying power might have been employed, still, that made use of indicates, if not the actual, at least the relative preventive tendencies of the various substances, which, practically, is the point of greatest importance. Yet, I think it will be admitted, that the 12th of an inch object-glass, magnifying about 711 diameters, is an instrument of no mean power, considering that germs in active motion, and measuring about $\frac{1}{40,000}$th (·000025) of an inch in diameter, can be seen by it.

The following bodies appear to merit special observation for

reasons which shall be obvious when referring to them—sulphate of copper, bichloride of mercury, sulphate of iron, arsenious, benzoic, hydrocyanic, picric, carbolic, and sulphurous acids, chloride of aluminum, chloride of calcium, bisulphite of lime, alcohol, chloral hydrate, bromal hydrate, caustic potash, hard soap, hydrochlorate of strychnia, acetate of morphia, chlorate, bichromate, and permanganate of potassium, Condy's fluid, salts of sodium, especially the chloride and borate; camphor, musk, cantharides, quassia, and capsicum.

Regarding sulphate of copper, as already stated, its average preventive point is very high, viz., 1-933·3. Why, is not very apparent, as it does not seem to possess any distinctive peculiarities other than being astringent, styptic, and escharotic, and that in a comparatively moderate degree.

The bichloride of mercury stands high, having an average of 1-663, which, however, is about 1-3rd less than that of the cupreous salt. This seems an unexpected result, considering its well-known powerfully corrosive, and acknowledged antiseptic properties, and might at first be attributed to its being rendered inert by combination with the albumen in that solution. But in the two other solutions, its preventive points are also about 1-3rd below those of the sulphate of copper; while that, like most other metallic salts, has also the property of forming an insoluble compound with albumen, and combining also with the nascent sulphuretted hydrogen. Again, its urinous solution, at the preventive point, has a faint putrescent odour; while the same solution of sulphate of copper, though 1-3rd weaker, is quite free from smell.

The ferrous sulphate, or proto-sulphate of iron, stands comparatively low in the albumen column, but has a fair average. This substance, if mixed with organic matter, possesses the power, in addition to the properties of the other metallic salts, of appropriating oxygen that would otherwise combine with that matter, and so induce putrefaction, which it thus delays. This power, however, is proportioned to the quantity of the salt present, and is, of course,

exhausted when its oxidation is completed. The organic matter, being then without any means of defence from its natural foe, oxygen, is now acted on by that element, and putrefaction ensues. The mixture, however, now contains the "ferric sulphate" (Fe_2O_3, $3SO_3$) instead of the "ferrous sulphate."

Arsenious acid—(a small quantity of "hydrochloric" had to be used to render this substance soluble). The violent symptoms which arsenious acid originates when swallowed, and its strong antiseptic action on the viscera of persons poisoned by it, are well known, yet its preventive powers are greatly inferior to those of the ferrous sulphate. Judging from the experiments, the explanation of this seems to be, that, as the latter salt surpasses the arsenic in preventive power, it would also surpass it as an antiseptic under similar circumstances.

Amongst the organic acids the "benzoic" is first in average, though third in the albumen column. This substance, it appears, has not received the attention it merits. No doubt gum benzoin has long been used in the preparation of fumigating pastiles to overcome unpleasant odours, but the general impression is that these are merely masked, not destroyed. The results of the experiments, however, indicate something more than this; because, although the albuminoid preventive point of picric acid is much higher than that of "benzoic," and though that of carbolic acid equals it, still it has an average greater than the former, and double that of the latter. Its mode of action is not clear; probably it is assisted by the small quantity of empyreumatic oil always present in its commercial crystals.

Hydrocyanic acid of the B.P. in its group stands second in the average, and first in the albumen column. As this solution, however, only contains one in fifty of the anhydrous acid, it follows that its real preventive point is 1-25,000, a power nearly double that of the united averages of each individual substance, which is only 1-14613; or, in other words, one minim of the pure acid has a preventive power nearly equal to that of two minims or grains

of each of the various substances combined. This acid seems to be the germicide "par excellence," stifling life amid putrefaction.

Picric acid, in its group, ranks next to hydrocyanic acid in the albumen column. It is easily obtained by mixing nitric and carbolic acids, when evolution of nitrous fumes ensues, with the formation of a tarry-looking residue—crude picric acid. It has an excessively bitter taste, a strong peculiar odour, and a yellow colour so singularly intense that it gives a perceptible tint to a million parts of water. Its *modus operandi* as a preventive agent is not very clear.

We now come to consider a substance which has recently risen to great importance, viz., "carbolic acid." Highly as I esteem my former teacher, Professor Lister, and greatly as I admire his patient, arduous research, and fertility of resource, all of which I had abundant opportunities of witnessing and profiting by while he was developing his theory of the "antiseptic system;" and satisfied as I am of the comparatively "marvellous results" which he and others have obtained, and are obtaining, with this substance, yet, the conclusion is irresistible from the experiments, that, if these results are to be attributed solely to the germ-killing or preventive powers of carbolic acid, then it must yield the palm to many superiors. If, as is alleged, germs are the source of putrefaction, then the strongest preventives *must* be the best antiseptics, and *vice versa.* Now, as seen in the table, carbolic acid occupies a very mediocre place as a preventive, therefore it is legitimate to conclude that it stands no higher as an antiseptic. But if it does not check putrefaction by killing germs, or directly preventing their multiplication, how, then, does it act? Although unable to formulate the change that takes place when it unites, in large proportion, with organic bodies, for which it has a strong affinity, still the result of such change certainly is the formation of a compound capable of resisting the attacks of oxygen, of water, and, consequently, of germs. In other words, a compound is formed which is proof against putrefactive tendencies.

The next substance—sulphurous acid—it was expected would have stood at the top of its group, seeing that a few years ago it was extolled by two Scotch medical practitioners as the "paragon of parasiticides." Here it is lowest as a germicide. It seems to act like the ferrous sulphate by appropriating the oxygen that would otherwise decompose the organic matter. Hence it is converted into sulphuric acid, which, however, stands at the top of the group. The cause of this apparent anomaly is not clear. Probably, from the sulphurous acid being volatile, a portion may escape oxidation, and thus the residual sulphuric acid is proportionately lessened.

Dr. Angus Smith, in his work on Disinfectants, states that "sulphurous acid deodorizes putrid matter (whether by giving or taking oxygen is not explained), but that if used in a liquid or moist substance containing organic matter (it was so in this instance), it is decomposed, and sulphuretted hydrogen given out."

Chloride of aluminum, amongst the salts of the alkaline earths, stands first. Its very high preventive power (1-2000) in the "hay solution," already noticed, seems remarkable, and was verified several times. It also shows a high average in the other solutions.

The commercial liquid known as "chloralum" has been included in this list. It is merely an aqueous solution of chloride of aluminum. As anticipated, its average is low.

Solution (saturated) of chloride of lime has a low preventive point (1-25) in the albumen column. This substance acts as an oxidizer, its chlorine combining with the hydrogen of the water, forming hydrochloric acid, while oxygen is liberated.

Bisulphite of lime.—This body is chiefly used in the preservation of flesh. As a preventive it stands much lower than sulphurous acid, a solution of which it greatly resembles.

The preservative powers of alcohol have long been known. These are the result of its strong attraction for water. As a preventive it stands below mediocrity.

Bromal hydrate and chloral hydrate stand at the top of the alcoholic series, and are above the average of preventives. Doubtless these bodies possess corresponding antiseptic properties.

The very low preventive power of potash in the albumen column (1-10) is worthy of note. Such a mixture is, obviously, highly caustic, and has a powerful softening and disintegrating action on organic tissues. Still, it was necessary to use it of such strength to prevent the appearance of life, as at 1-25 bacteria, &c., were abundant. It seems incredible that creatures so seemingly fragile, so astoundingly minute and numerous, that the more common infusorial animalculæ are Titans in comparison, and could swallow a shoal of them in a mouthful, can exist in a liquid so corrosive as to produce sloughing, if kept for a short time in contact with the skin, and to cause certain death in the human subject, if swallowed in small quantity. Their bodies seem composed of some chitonous, or insoluble substance resembling caoutchouc or gutta percha, all of which are unaffected in solutions of the alkalies.

Anhydrous stearate of soda or hard soap has a very low preventive average (1-25), at which point it is of the consistency of curdled milk. From a sanatory point of view this is a fact of importance, as it proves that though soap, in conjunction with water and friction, be an excellent detergent in virtue of its solvent action on effete organic matter, yet it does not follow that it is even a moderate preventive. It might be worth considering whether a domestic soap could be made at a cheap price, combining good detergent, with the highest preventive, powers.

The hydrochlorate of strychnia, notwithstanding its energetic toxic action on the higher animals, is only a moderate preventive.

The acetate of morphia is powerless as a preventive in the "albuminous solution," and nearly so in the "urinous."

Chlorate of potassium. From the high character borne by this substance as a gargle or wash, in cancrum oris, gangrenous stomatitis, diptheria, &c., where it is supposed by some to act by

destroying certain fungi, or germs, or specific poison, it was expected that it might have a high preventive power, whereas it is blank both in the urine and albumen columns. Moreover, it was observed that it has very remarkable power in hastening decomposition.

The permanganate of potash stands second in its group, but has a comparatively low average; its albuminoid mixture at the strength noted is of the consistence of jelly.

Condy's fluid is blank both in the urine and albumen column.

With the exception of hydrocyanic acid, the bichromate of potassium stands unrivalled as a preventive in the albuminoid solution, and, besides, has a very high average. It is superior, however, to hydrocyanic acid in respect that its urinous and albuminous solutions, at the preventive points, are quite sweet and pure, while those of hydrocyanic acid have a distinct putrid odour. In a sanatory sense, this substance seems to merit more attention than it has hitherto received. Dr. Angus Smith shews, in a table of experiments, in his work on disinfectants, "to determine the amount of each of 14 of the most energetic antiseptic bodies necessary to prevent the evolution of sulphuretted hydrogen in a mixture of equal parts of blood and water," that all of them, in from six to ten days, had evolved more or less of that gas, except the one containing bichromate of potassium. It is strong proof of the decided and valuable antiseptic powers of this salt, that the same result should be gained by two different observers, using two different tests—*i.e.*, the evolution of sulphuretted hydrogen, and the appearance of animalculæ, and the one also being unaware of the results obtained by the other. It seems, also, a proof that antiseptics act on the putrescible matter, and not on the germs, as free access of air was allowed, the bichromate not being volatile.

The hyposulphite, borate, sulphate, and chloride of sodium, are almost useless as preventives, being blank in the urine and albumen columns. These compounds, in the circumstances, de-

cidedly accelerate decomposition, and it is worthy of observation that here *common salt stands lowest in preventive power.* Dr. Gregory, in his "Organic Chemistry" (page 33), states that "the presence of bases greatly promotes the absorption of atmospheric oxygen by organic substances, which is the reason why alkalies assist *erema causis.*"

The extract of capsicum, of cantharides, of quassia, and tincture of musk—preparations which it was thought might prove good preventives—are comparatively worthless.

There are a few other bodies that merit particular attention, but the short time at my disposal precludes me from noticing them.

One substance, however, viz., Chromic acid, I much regret was not included in the list. Having observed, after the tables were arranged and this paper written, the great difference in the preventive powers of bichromate of potassium and of potash, it was surmised that probably the potency of the former body resided in its acid, of which it contains two equivalents. Desirous that this point should be settled, even though too late to embody the issues in the table, Chromic acid was subjected to the same tests as the other substances, and the results fully confirmed these anticipations.

PREVENTIVE POWERS OF CHROMIC ACID.

Hay, 1-4000. Urine, 1-1400. Beef Juice and Egg Albumen, 1-1200.
Average, 1-2200,

With the exception, therefore, of Hydrocyanic acid, Chromic acid surpasses all the substances enumerated as a preventive; and without exception, all, as an antiseptic. Were it placed in its proper position in the table, it would raise its group (the inorganic acids) from the fourth to the first place.

Chromic acid is unquestionably an antiseptic of surpassing power, and must ere long take the foremost place as a sanatory agent. If brought in contact with organic matter CrO_3—Chromic acid, or teroxide of Chromium, is reduced to Cr_2O_3—sesquioxide of Chromium, one and a half equivalents of oxygen being liberated for each molecule of the acid decomposed. It is therefore, both

theoretically, and, as I have ascertained, practically, an excellent deodorant, while it possesses, at least, *double the antiseptic power of carbolic acid.* It is also perhaps a stronger coagulator of albumen than any other chemical substance. As such, it greatly exceeds carbolic acid, nitric acid, &c. Moreover, it is extremely soluble in water, a property of primary importance so far as the disinfecting of clothing and the prevention of putrefaction is concerned. It is also perfectly devoid of odour. It may be objected that it is not volatile; but this might be obviated to a considerable extent, if desired, by using its aqueous solution in the form of spray. Still, in many instances, volatility in reference to antiseptics and disinfectants is a property which, in their practical application, is not always to be regarded as a recommendation; because their maximum sanatory effect cannot be obtained unless they are used much stronger than can be tolerated by the senses, and in enclosed spaces, necessitating, in either case, the removal of any occupants. As commonly employed, there is much reason to believe that, in the majority of cases, they merely disguise, or, at best, only palliate, offensive odours.

Further, in a sense, even their volatility is an objection, inasmuch as they are liable to be dissipated or diluted by atmospheric air to a degree which renders them comparatively inert either as antiseptics or disinfectants.

Although it was not made a point of special attention in the experiments to ascertain whether, and if so, at what rate, any of the substances accelerated or retarded putrefaction, still it was observed, as already partially stated, that (except the bichromate of potassium) the alkaline salts, caustic potash, sulphate of magnesia, and spirits of nitrous ether greatly hastened it.

Again, among many of those bodies whose preventive points show a fair average, there was a difference of from two to four days in the occurrence of decomposition. Of course this was only ascertained at strengths below their preventive points.

In every case where the odour of putrefaction was strong, excepting the caustic potash and albumen solution, large and small animalculæ were abundant. In a few cases, where it was faintly perceptible, these were absent; and in a few, where no odour could be detected, only the most minute germs were present. Commonly, where the mixture kept free from odour, germs were absent. In some of the solutions, more especially the albuminous with chloroform, only the very minutest germs could be perceived previous to the sixth day, and these always in such myriads, that though magnified fully 700 diameters, they gave the field of the microscope the aspect of the finest "stipling" or punctate grain work of the engraver, visible to the naked eye.

The smaller forms seem to possess greater vital energy than the larger, as they are first and last seen in the solutions.

These are the chief replies which were obtained to my frequent and probably peculiar interrogations of nature. Several inferences and questions arise from these, some of which have already been, of necessity, cursorily considered.

First.—It does not appear that germs are the cause of putrefaction, because in several of the urinous solutions, viz., that with chloroform, chloral hydrate, tartaric acid, chloride and sulphate of aluminum, sulphate of zinc, camphor, soap, hydrocyanic acid, hydrochloric acid, tartrate of antimony, and bichloride of mercury, germs were absent, while they had, at the same time, a faint but distinct putrescent odour. It is not likely that this absence of life is attributable to any exclusive property of these bodies, but rather that their solutions were examined at a stage immediately preceding the appearance of germs, a state which all the solutions probably passed through, and which, if looked for at the proper time, might be found in any of them. Curiously enough, however, these conditions existed only in the "urinous," while the very opposite are found in the "albuminous" solutions, viz., the presence of germs, and the absence of putrid odour. Caustic potash and albumen is, however, an exception, the

odour being, as already stated, very putrid and germs absent. Of course, this was ascertained during the experiments to find the various preventive points. The bodies with which it occurred were carbolic, acetic, benzoic, and hydrochloric acids, permanganate of potash, solution of chloride of lime, sulphate of copper, and ferrous sulphate. It is possible that in some of these cases the nasal organ, which is more liable to derangement of function than the eye, may have been deceived, or, that the odour of putrefaction may have been masked by the smell of some, at least, of the extraneous substances. In any view, that the fluid was in a state of incipient decomposition, though not appreciable by its smell, I submit was satisfactorily evinced by the presence of bacteria and vibriones in considerable numbers. The reason why life preceded odour in the albuminous fluid need not, I think, be ascribed to any property of the chemical substances, but rather to the rich quality of the fluid forming a most favourable nidus, and suitable pabulum, for the multiplication of these active creatures. Germs may thus precede odour, but decomposition more or less precedes germs. As observed by Beale, "active bacteria, introduced into a healthy wound, or among the living tissues, will die, although the most minute germs present, which escape death, may remain embedded in the tissues in a perfectly quiescent state." And again, "bacteria germs grow and multiply wherever a change takes place in the solids and fluids of the organism, which develops compounds suitable for the pabulum of these living bodies."—(Disease Germs: their Supposed Nature, p. 59.)

On the other hand, the reason why the odour of putrefaction preceded the appearance of life in the urinous solutions, is probably owing to the chlorides, free acid, &c., in that fluid, preventing the development of germs till decomposition had somewhat advanced; but whatever be the cause, the fact remains patent, viz., that *slight*, and in one case (potash and albumen) *extensive*, putrefaction may exist while none of these bodies are present, proving that germs are not the cause of that process.

But we may go further than this, by stating that it is more than probable that *germs rather prevent putrefaction.* You have doubtless all read, and pondered over, the broad and brilliant philosophical deductions, which seem, to me, to compose the fairiest of all "the fairy tales of science," regarding the uses in nature of infusoria, by that illustrious and veteran master in natural history, Professor Owen.

"Consider," he says, "their incredible numbers, their insatiable voracity, and that it is the particles of decaying vegetable and animal bodies which they are appointed to devour and assimilate. Surely we must in some degree be indebted to those ever-active invisible scavengers for the salubrity of our atmosphere. Nor is this all. They perform a still more important office, in preventing the gradual diminution of the present amount of organic matter upon the earth; for when this matter is dissolved and suspended in water in that state of comminution and decay which immediately precedes its final decomposition into the elementary gases, and its consequent return from the organic to the inorganic world, these wakeful members of nature's invisible police are everywhere ready to arrest the fugitive organized particles and turn them back into the ascending stream of animal life. Having converted the dead and decomposing particles into their own tissues, they themselves become the food of large infusoria, and of numerous other small animals, as the rotiferæ, which in their turn are devoured by larger animals, as fishes; and thus a pabulum fit for the nourishment of the highest organized beings is brought back by a short route from the extremity of the realms of organic matter."— (On the Invertebrata.)

Here one individual designates germs "ever-active invisible scavengers," whose duties are to polish our sunbeams, purify our atmosphere, and sweeten our waters; "wakeful members of nature's invisible police," who are ceaselessly collaring and gobbling up the organic runaways, so as to prevent them injuring their more sensitive neighbours, as well as themselves. Others, again, and

especially Professor Lister, denounce them as the cause of many, perhaps of most, diseases—the invisible and ruthless scourge of our hospitals, often in a few hours rendering hopelessly abortive the best-directed remedial measures; and, therefore, a war of extermination, or a "stamping out" procedure, ought to be perpetually waged against them. Between two such eminent authorities differing so widely, it is difficult to decide without exact data. These, it is considered, have been indicated, if not furnished, by the experiments, the results of which agree with the opinion of the great majority of those who have studied the subject.

How is it that germs have at all come to be considered as the cause of putrefaction? I presume, from the fact, that along with fungi, they are generally found in decomposing organic solutions. But assuming them to be the scavengers which Professor Owen says they are, then that is just where they ought to be, and just where we should expect to find them.

If meat or vegetables are found fresh some months after being hermetically sealed in tins from which the air has been exhausted, or, after having absorbed some substance with the property of preventing fermentation, or putrefaction, it is concluded that this is owing to the absence of germs: instead of that the absence of germs is owing to the freshness of the substances.

Helmholtz, Pasteur, and others seem to have shewn that germs may be mechanically excluded from organic solutions, with the result that the fluid does not get turbid. But these experiments appear more adapted to illustrate the theory of Biogenisis, than that germs are the cause of putrefaction. It has probably been already proven that the phenomenon of putrefaction originates in some other cause than the presence of germs, and that it necessarily precedes their appearance. Moreover, it seems a just inference that their exclusion will prolong the putrefactive process by allowing entire decomposition to ensue, but will not stop it.

It is generally considered that when a decomposible fluid remains destitute of haze and mouldiness, it is not decomposing. What is this haze and mouldiness? Animalculæ and fungi—nature's invisible sanatory executive—which Helmholtz with his membrane, Dusch and Schröder with their cotton wool, Schwann with his red-hot glass tubes and fuming sulphuric acid, and Pasteur with his crooked-necked flasks, are supposed to intercept or suppress in the course of their sanatory duties. Conversely it is held that the proof of putrefaction in an organic solution is a growing haze and mouldiness in it (*i.e.*, animalculæ and fungi). Very good; but the proof of a thing is not necessarily the cause of it, any more than a municipal sanatory officer is the cause of the municipal filth and fever, he being only a sign of it; or any more than the absence of the proof indicates the absence of the thing itself. But further, the proof may actually be antagonistic to the cause, as animalculæ, though indicating decomposition, are busy preventing it; as the presence of the fire brigade indicates fire, while its members are extinguishing it.

Again, as already stated, commonly where the mixture kept free from *appreciable odour and haze*, germs were absent. Some may say that this absence of putrefaction was owing to the absence of germs; but I am inclined to hold that the absence of germs was rather owing to the absence of putrefaction, and the absence of putrefaction owing to the presence of an antiseptic. No means were taken to exclude germs, but rather the reverse. Why, then, were they absent here? Simply because they were not required. And how did they happen to stay away when not required? Because the conditions favourable to their active existence and increase, and which it is their natural function to prevent, were absent. Conversely, when these conditions prevail, they are present. Thus the oscillations of decomposition and recomposition are seen to be compensatory.

After these observations, it will scarcely excite surprise if it be asked, *Is it necessary to kill germs?* and, considering their

numbers and size, *Is it possible*, even supposing their destruction would be of any conceivable benefit?—and the answer be, It is as unnecessary as it is impossible. Their services may be dispensed with by substituting better scavengers, or by preventing the noxious conditions which nature has appointed them to obviate; but in such cases they will save you the trouble of killing them, by leaving spontaneously in search of a living elsewhere. Again, while it seems possible to supersede them by more energetic artificial means, and to prevent, to a great extent, the conditions that require removal, still the results of the experiments appear to indicate that it is also possible to substitute worse scavengers (*i.e.* substances that accelerate putrefaction), and even to remove the natural ones without replacing them by others, (as in those substances which are putrid at the preventive point.)*

In the foregoing remarks no reference is made to the "fungi" which were frequently present, especially in the vegetable solutions, and were observed generally before, but often simultaneous with, the motile bodies.

The vitality of these plants is more easily overcome than that of the animalculæ, because they always disappeared from the solutions before the latter. "Although some hold that fungi are both the predisposing and exciting causes of certain diseases in man and animals with which they are associated, yet it is generally believed that the positions in which they are found are their natural ones, and that they only grow and multiply on dead organic matter, or on organisms in which the vital powers are deteriorated, and the healthy processes of life consequently imperfectly performed."

Assuming the latter view as the correct one, then fungi, like animalculæ, are also scavengers. Their myriad spores, which are constantly floating in the air, alighting on organic matter in an incipient state of decay, strike their roots into it, and begin to recompose it into their own structures.

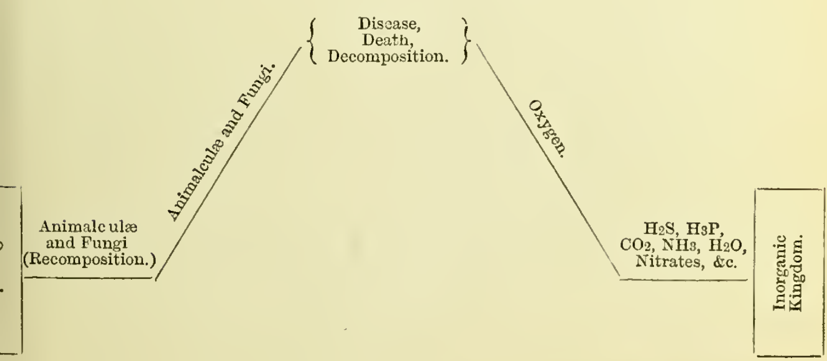
* See also table at end.

Thus, though these plants may be considered, like their congenors, the animalculæ, as a sign of decay, which they undoubtedly are, yet the great majority of facts tend to show that they are not the cause of that process, but the consequence, the symptoms of decomposition, but, at the same time, the tangible proofs of recomposition. Remove, or prevent the morbid states which yield a soil suitable for their germination and multiplication, and they will cease to germinate and multiply. Remove the cause and the symptoms will disappear.

Second—What is the cause of putrefaction? Having in some degree, perhaps, proven that animalculæ and fungi rather prevent than cause putrefaction, it may now be attempted to show, what is already very generally admitted, that putrefaction is also caused by a scavenger, the name of which is Oxygen.

The operations of this body, like those of its animal and vegetable co-workers, are, however, preceded by others, viz., diminished vitality or death of the organism, which may again proceed from a variety of states inimical to health and life. The method of procedure of oxygen in its incessant labours to keep sweet and pure the abodes of organic nature, is to dissolve complex aggregations of matter by, at least, initiating chemical transposition, and sweep the metamorphosed and disunited molecules back into the inorganic world in the form of sulphuretted hydrogen, phosphuretted hydrogen, carbonic acid, ammonia, water, nitrates, &c. Therefore we have—

Conditions Inimical to Health, Producing



Third.—In what manner do substances prevent the appearance of animalculæ and putrefaction?

1. Is it by exhaling constantly a destructive atmosphere on their myriads which are perpetually swarming in the neighbourhood of organic matter? It does not appear that the substance mixed in the organic solution at, or even above, its preventive strength, and though volatile, has any effect on germs at, or near, its surface, but not actually in the solution; because if an open phial, containing beef juice only, be suspended in an open flask also containing beef juice, but to which has been added the ascertained preventive quantity of either a volatile or fixed substance, it will be found, that, though neither life nor putrescence appears in the latter, the former will, in about three days, be teeming with life, and quite putrid. This experiment may be varied by using hay or urine, with the same results. Germs and putrefaction being practically synonymous, the preventive point of a substance may, therefore, be taken as a measure of its antiseptic power.

2. Is it by destroying their ova? I think it must be assumed that "the preventive" either permanently destroys the ova, or suppresses their development for an indefinite time, or renders the soil inimical to their growth, whether they be considered as lodged in the putrescible substance previous to the addition of "the preventive," or as being continuously depositing on it subsequently.

3. Is it that the compounds necessary to evolve life "de novo" are chemically changed by the preventive, so that life is incompatible with the altered conditions?

If spontaneous evolution be regarded as possible, this seems the only explanation, and implies alterations in the molecular structure and sensible properties of the organic substance which, though difficult to formulate, may easily be considered, from the known characters of the given preventive, as amply sufficient to account for the non-apppearance of life.

Before concluding, I wish to direct attention to the following

table of experiments, which were made with the view of ascertaining the relative germicidal and deodorizing powers of the various substances at their ascertained preventive points. A deviation was made from one of the original conditions of the previous experiments, which, though it has not interfered with the unity of the table by itself, has partly depreciated its value, inasmuch as it results cannot be justly compared with those of the preceding table. The change referred to is, that equal parts of the preventive and putrid solutions were used, whereas in the former tables only one part of the albuminous mixture was added to seven parts of the preventive fluid. Had the latter instead of the former proportions been tried in these experiments, the result would have been undoubtedly more negative, but therefore more uniform with those previously obtained.

Viewing the table, however, as a group of independent results obtained under identical conditions, it was thought that it might not be uninteresting to append it to this paper, seeing that it is so nearly allied to the main subject, and consists exclusively of actual facts, from which a great many important conclusions may be drawn, but which are submitted without observation.

TABLE

Shewing the results of adding an equal part of a putrid solution of Beef Juice and Egg Albumen, full of Animalculæ, to solutions of various substances of strengths known to be preventive.

I. SUBSTANCES THAT DESTROY LIFE BUT NOT SMELL.*

NAME OF SUBSTANCE.	Strength.	Effect on Animalculæ in 15 minutes after mixing the Solutions.	Whether the Mixture is deodorised.	Whether Animalculæ are present after four days.	Condition after four days as to Odour.
Sulphate of Copper,	1-800	Death.	No.	A few vibriones.	F. P. †
Stearate of Soda (Hard Soap), . .	1-25	Death.	No.	No.	Putrid.
Sulphate of Beberia,	1-25	Death.	No.	Abundant.	F. P.
Chloride of Zinc, .	1-300	Death.	No.	No.	None.
Nitric Acid, . .	1-200	Death.	No.	No.	None.
Nitro-Hydrochloric Acid, . . .	1-100	Death.	No.	No.	None.
Hydrochloric Acid,.	1-100	Death.	No.	No.	None.
Hydrochlorate of Arsenic, . .	1-50	Death.	No.	No.	None.
Benzoic Acid, . .	1-200	Death.	No.	No.	None.
Acetate of Lead, .	1-300	Death.	No.	Abundant.	Very putrid
Sulphate of Iron and Potassium (Iron Alum)	1-300	Death.	No.	Abundant.	Very putrid
Sulphuric acid, .	1-100	Death.	No.	Very abundant.	Very putrid.
Sulphate of Zinc, .	1-300	Death.	No.	No.	Very putrid
Caustic Potash, .	1-10	Death.	No.	No.	Very putrid
Sulphurous Acid, .	1-50	Death.	No.	No.	F. P.
Bisulphite of Lime,	1-25	Death.	No.	No.	F. P.
Oxalic Acid, . .	1-200	Death.	No.	No.	None.

II. SUBSTANCES THAT DESTROY LIFE AND PARTLY SMELL.

Bichromate of Potassium, . . .	1-900	Death.	Considerably.	A few vibriones.	F. P.
Tincture of Iodine, .	1-50	Death.	Partly.	No.	F. P.
Hydrochlorate of Strychnia, . .	1-300	Death.	Partly.	No.	None.

III. SUBSTANCES THAT DESTROY BOTH LIFE AND SMELL.

OL, . . .	1-20	Death.	Yes.	No.	F. P.
ION OF CHLORIDE IME, . .	1-25	Death.	Yes.	No.	None.
RIDE OF MERCURY	1-500	Death.	Yes.	No.	None.
ACID, . .	1-350	Death.	Yes.	No.	F. P.

IV. SUBSTANCES THAT PARTLY DESTROY SMELL BUT NOT LIFE.

L HYDRATE, .	1-500	Myriads of active Vibriones.	Partly.	No.	None.
OR, . .	1-50	Myriads of active Vibriones, also large Animalculæ.	Partly.	No.	None.
AL HYDRATE, .	1-300	Myriads of active large and minute Animalculæ.	Partly.	No.	Putrid.
LIC ACID, .	1-200	Teeming with Vibriones.	Partly.	No.	F. P.

V. SUBSTANCES THAT DESTROY SMELL BUT NOT LIFE.

TE OF SILVER, .	1-50	Myriads of minute life.	Yes.	Abundant.	F. P.
NGANATE OF SSIUM, . .	1-25	Teeming with minute life.	Yes.	No.	F. P.

VI.—SUBSTANCES THAT NEITHER DESTROY LIFE NOR SMELL.

TE OF AMMONIUM,	1-25	Myriad life.	No.	Abundant.	Putrid.
US SULPHATE, .	1-100	Abundant minute life.	No.	Abundant.	Very putrid.
CYANIC ACID, .	1-500	Abundant life.	No.	No.	F. P.
LORIDE OF FOR- E (Chloroform),	1-25	Life.	No.	No.	None.
ATE OF ANTIMONY,	1-300	Abundant life.	No.	Abundant.	Putrid.
TE OF SODA, .	1-25	Abundant life.	No.	Abundant.	Very putrid.

* The headings of the various divisions refer exclusively to the results tabulated in the third d fourth columns.

† F. P. denotes faint putrescence.

NOTE.—In the above table, with two exceptions—nitrate of silver and permanganate of potassium— is always accompanied by putrefaction, though the converse is not the case—another proof t germs are not the cause of putrefaction.